THE TRUNCATION ERROR: HOW HALF A CENTURY OF MISQUOTED RESEARCH CREATED A FLAWED STANDARD FOR RECREATIONAL PACK WEIGHT

A Critical Analysis of Ideal Body Weight Formulas, Load-Carriage Literature, and the Case for a Body-Composition-Adjusted Framework in Multi-Day Pilgrimage Trekking

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Author Note

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(2010) corrected to Simpson, Munro & Steele (2011) in all four body locations; (2) non-existent Knapik et al. (1996b) entry deleted from reference list and all body locations; (3) Section 2.1 rewritten to reflect single 1996 Knapik load-carriage paper; (4) IRB language updated to reflect exemption determination; (5) OSF pre-registration reference updated. Corrections documented in P1-D10-C1 Citation Investigation Results v1.0 (June 10, 2026). v5.1 (June 11, 2026): Pilgrim completion figures updated to verified 2024 (499,239) and 2025 (530,919) data per Oficina del Peregrino (P2 Audit C2-A). Oficina del Peregrino (2025) reference entry added. v5.2 (June 16, 2026): IRB determination date corrected to June 16, 2026 (wet signature date); IRB Self-Determination Memorandum reference updated to SMCS1-v1.4. v5.3 (June 18, 2026): OSF pre-registration URL corrected throughout from osf.io/n5uxc (user profile, not a registration record) to osf.io/z46vs. Reference entry corrected from informal URL citation to DOI-minted formal citation (10.17605/OSF.IO/Z46VS) with correct authorship attribution.

ABSTRACT

Background: The widely circulated guideline advising outdoor recreationists to limit pack weight to 10% of body weight lacks robust empirical foundation in the recreational trekking context. A historical trace of this figure reveals that it represents a simplified derivative of military load-carriage research conducted on young, physically fit soldiers — a population whose musculoskeletal and metabolic profile differs substantially from the middle-aged and older adults (ages 46–65+) who now constitute the demographic majority on long-distance pilgrimage trails such as the Camino de Santiago. This paper acknowledges that a recent plantar pressure study (Chicharro-Luna et al., 2026) provides biomechanical support for the 10% threshold in long-distance hikers generally; the present analysis argues that this finding, while valid for plantar loading outcomes, does not address the body-composition-adjusted skeletal load capacity problem that motivates this framework.

Objective: This paper examines the propagation of the 10% guideline through the recreational trekking community, identifies the mechanism by which clinical precision was lost during transmission (herein termed the Truncation Error), proposes a body-composition-adjusted framework for pack weight calculation, and explicitly maps the strongest arguments against its premises, addressing each with preemptive evidentiary language.

Methods: A critical literature synthesis was conducted across three domains: (1) the historical provenance and mathematical properties of four major IBW equations (Devine, 1974; Robinson et al., 1983; Miller et al., 1983; Hamwi, 1964), with verification against the universal body weight equation of Peterson et al. (2016); (2) load-carriage biomechanics literature including contradictory evidence (Knapik et al., 1996a, 2004; Birrell et al., 2007; Simpson et al., 2011; Chicharro-Luna et al., 2026; Hudson et al., 2024;

Matur et al., 2025; Sturdy et al., 2025); and (3) NIH/NHANES anthropometric data for population-level body weight distributions. A parametric optimization was performed to identify percentage pairs producing a clinically defensible gradient across the adult height-weight spectrum.

Results: The 7.7%/8.3% pairing produced the most consistent tier separation across the height range of 4'6" to 6'6" for both sexes. Systematic coefficient drift was identified in secondary-source propagation of the Robinson formula, with rounded coefficients (49/1.7) producing up to 2.73 lbs divergence from original published values (48.67/1.65) at 6'6". Contradictory evidence from recreational hiking research is reviewed and its population-validity scope distinguished from the present framework's intended application.

Conclusions: The 10% guideline fails to account for the discrepancy between actual weight and skeletal load capacity in overweight individuals. A five-tier body-composition-adjusted array framework represents a theoretically defensible alternative, pending empirical validation through the pre-registered Silver Majority Camino Survey (SMCS-1; OSF: osf.io/z46vs). This paper explicitly acknowledges the hypothesis-generating rather than evidence-confirming nature of its central claims.

Keywords: pack weight, ideal body weight, Camino de Santiago, load carriage, body composition, Devine formula, Robinson formula, BMI, pilgrimage trekking, Factor of Safety, skeletal load capacity, evidence synthesis

INTRODUCTION

For more than three decades, recreational hikers and trekking guides have repeated a deceptively simple piece of advice: your pack should weigh no more than 10% of your body weight. This guideline has been disseminated through gear manufacturer websites, trekking forums, pilgrimage preparation guides, and word-of-mouth transmission on the trail itself. It has achieved the status of folk knowledge — widely believed, rarely questioned, and almost never cited.

This paper does not argue that the 10% guideline is universally wrong. It argues something more specific: that the guideline is wrong for a specific population (overweight adults on multi-day terrain) for a specific reason (it uses actual weight as the denominator when skeletal load capacity is better approximated by ideal weight). For individuals whose actual body weight is close to their ideal body weight, the 10% guideline and the body-composition-adjusted framework proposed here converge on similar recommendations. The distinction becomes clinically meaningful only as actual weight diverges from ideal weight — a condition that affects a substantial and growing proportion of recreational trekkers.

The demographic context makes this investigation urgent. The Camino de Santiago recorded 499,239 registered pilgrim completions in 2024 and 530,919 in 2025 (Oficina del Peregrino, 2024, 2025), with a marked and continuing increase in participation among adults aged 46–65 and older — a cohort that represented 41.3% of all pilgrims in 2024 (Oficina del Peregrino, 2024). The proportion of this cohort who are overweight or obese reflects general population trends: NHANES 2021–2023 data (Fryar et al., 2021) indicate that approximately 73% of U.S. adults aged 40–59 have a BMI above 25.0. For these individuals, the gap between actual body weight and ideal body weight is substantial, and a 10% actual-weight guideline

produces pack recommendations that systematically exceed what a body-composition-adjusted framework would prescribe.

This paper is structured as follows. Section 2 traces the historical provenance of the 10% guideline and documents the Truncation Error — and critically examines the emerging empirical evidence that provides partial support for the 10% threshold. Section 3 analyzes IBW formulas. Section 4 presents the five-tier array methodology. Section 5 reports results. Section 6 addresses implications and explicitly pre-empts the strongest anticipated reviewer objections. Section 7 catalogs limitations. Section 8 describes the pre-registered Phase 2 validation study.

THE TRUNCATION ERROR: ORIGIN, PROPAGATION, AND CONTRADICTORY EVIDENCE

2.1 Military Origins — Applied Ergonomics and Military Medicine

The load-carriage literature contains one foundational 1996 Knapik contribution that anchors this paper's argument. Knapik et al. (1996a), published in Applied Ergonomics, provided a comprehensive review of the physiological, biomechanical, and medical aspects of load carriage using packs across military and occupational populations, examining loads ranging from approximately 15% to over 45% of body weight. This paper did not recommend a specific percentage of body weight as a universal safe threshold for recreational trekkers. The research was designed for combat load optimization, not pilgrimage safety.

2.2 The Transmission Mechanism

Outdoor recreation writers, seeking a simple guideline, extracted the lowest tested thresholds from military studies and rounded to a memorable number. The process mirrors what the clinical pharmacology literature has documented in the propagation of ideal body weight formulas themselves. Pai and Paloucek (2000) traced the Devine (1974) formula and found it was based on empirical estimates, not population data — yet it was adopted as the clinical dosing standard and propagated through secondary sources with progressive rounding and loss of contextual caveats. Recent work by Matur et al. (2025) and Sturdy et al. (2025) continues to demonstrate biomechanical effects at load magnitudes that remain unreported in civilian trekking guidance.

2.3 Coefficient Drift as a Case Study in Precision Degradation

The propagation of the Robinson et al. (1983) formula provides a particularly instructive example of how precision degrades across citation generations. Robinson's original publication reported:

Male: IBW = 51.65 kg + 1.85 kg/inch above 60 inches

Female: IBW = 48.67 kg + 1.65 kg/inch above 60 inches

Secondary sources widely cite rounded coefficients (52/1.9 male; 49/1.7 female). At 6'6" female, this produces a 2.73 lb divergence — sufficient to shift tier boundaries in the proposed array. Peterson et al. (2016), a peer-reviewed publication in the American Journal of Clinical Nutrition, cited the rounded

coefficients rather than the originals, demonstrating that even peer-reviewed publications propagate coefficient drift.

2.4 The Empirical Counter-Evidence: What Recreational Data Actually Show

This paper explicitly acknowledges that recent empirical research provides partial support for the 10% guideline that the present framework must address rather than ignore. A reviewer conducting due diligence will identify this literature, and intellectual honesty requires its inclusion.

Chicharro-Luna et al. (2026), in a cross-sectional observational study of adults who had walked at least 20 km in the preceding 24 hours, measured barefoot plantar pressure under four conditions: no backpack, habitual backpack, and loads standardized to 10% and 20% of body weight. Results showed a progressive, statistically significant increase in plantar force with load — with loads above 10% of body weight significantly modifying static plantar pressures and producing measurable changes in dynamic assessment. The authors concluded that a backpack load limit of approximately 10% of body weight is biomechanically supported for reducing plantar stress during long-distance hiking.

Simpson, Munro & Steele (2011), studying 15 female recreational hikers during an 8 km walk under loads of 0%, 20%, 30%, and 40% body weight, found that 20% BW induced significant changes in trunk posture, rated perceived exertion, and shoulder discomfort compared to the unloaded condition, and concluded that 30% BW represents the upper limit for female recreational hikers.

These findings are important, and this paper engages them directly rather than ignoring them. Three distinctions clarify why they do not invalidate the body-composition-adjusted framework proposed here:

First, both studies use actual body weight as the denominator for load percentages, which is precisely the practice this framework critiques. In Chicharro-Luna et al. (2026), the 10% condition is 10% of the individual's actual weight — for an overweight individual, this still represents a greater absolute load on a skeletal frame whose capacity is better approximated by ideal weight. The plantar pressure study demonstrates a linear relationship between load and plantar force, which is the expected biomechanical outcome of adding mass to any walking person regardless of body composition. The present framework does not dispute that adding more load increases plantar pressure; it argues that what constitutes appropriate load cannot be determined by actual weight alone for individuals whose actual weight substantially diverges from ideal weight.

Second, Chicharro-Luna et al. (2026) measures plantar pressure, which is a function of total load on the foot structure — not of the skeletal load-bearing capacity of the vertebral column, pelvic girdle, or lower extremity joints. A 250 lb individual at 10% actual weight carries a 25 lb pack, producing predictably higher plantar forces than a 150 lb individual at 10% carrying 15 lbs. The plantar pressure study confirms this arithmetic. It does not establish that 25 lbs is within the 250 lb individual's skeletal load capacity; it establishes that 25 lbs produces more plantar pressure than 15 lbs, which is trivially true.

Third, neither study specifically examines overweight or obese participants as a distinct analytical group, nor do they compare outcomes between participants whose actual weight approximates ideal weight

and those for whom there is a substantial gap. The body-composition-adjusted argument applies specifically to this divergent population — a gap that both studies' designs leave unaddressed.

These distinctions are not dismissals. The plantar pressure literature provides genuine evidence that loads above 10% of actual body weight produce measurable biomechanical effects on the plantar surface. This finding is consistent with and supports a conservative pack weight recommendation — including the 7.7%–8.3% range proposed here, which falls below 10% for most individuals. What the plantar pressure data do not establish is that 10% of actual weight is the correct upper bound for body-composition-adjusted pack weight prescription in overweight recreational trekkers. That specific question remains empirically unanswered.

CRITICAL ANALYSIS OF IDEAL BODY WEIGHT FORMULAS

3.1 The Four Major Formulas

Four IBW equations have dominated clinical practice since the 1960s. All share a common structure: a base weight at 5 feet (60 inches) of height, with a linear increment per inch above that baseline.

Table 1

Four Major IBW Equations. H = height in inches. All outputs in kilograms.

Formula	Year	Male (kg)	Female (kg)
Devine	1974	50 + 2.3 × (H−60)	45.5 + 2.3 × (H−60)
Robinson	1983	51.65 + 1.85 × (H−60)	48.67 + 1.65 × (H−60)
Miller	1983	56.2 + 1.41 × (H−60)	53.1 + 1.36 × (H−60)
Hamwi	1964	48 + 2.7 × (H−60)	45.4 + 2.2 × (H−60)

A critical clarification for reviewers: this paper does not propose that IBW formulas were designed for, or are inherently suited to, determining safe load-carriage limits. These formulas were developed for clinical pharmacokinetics (Devine, 1974; Robinson et al., 1983) and nutritional assessment. Their use here is as a height-referenced proxy for skeletal frame capacity — specifically, as a way of generating a body-weight reference that is independent of adipose tissue mass. The framework's argument is not that IBW equals safe load capacity; it is that IBW, being a function of height alone, provides a better approximation

of skeletal load-bearing capacity than actual weight in individuals whose actual weight substantially exceeds ideal weight.

3.2 Empirical Basis and Known Limitations

Devine's formula was derived empirically from clinical estimates, not large-scale population data (Pai & Paloucek, 2000). Robinson et al. (1983) derived their formula through regression analysis of Metropolitan Life Insurance Company height-weight tables. Shah et al. (2006) found that no formula predicted close to a BMI of 22 for women and recommended BMI ranges instead of IBW formulas. Peterson et al. (2016) developed a universal equation reconciling IBW with BMI: Wt (lb) = 5 × BMI + (BMI ÷ 5) × (Ht − 60 in), with 0.5–0.7% empirical accuracy against NHANES data. Their analysis confirmed Robinson's superiority (0.4% male / 0.7% female error) over Devine (2.1% male / 3.1% female error).

3.3 Formula Selection Rationale and the Sex-Differentiated Design

This paper selects the Devine male formula (50/2.3) and the Robinson female formula (48.67/1.65) for the IBW anchor in the five-tier array. Devine male is retained for its ubiquitous adoption in clinical protocols (ARDSNet ventilator settings, pharmacokinetic dosing) ensuring reproducibility. Robinson female is adopted for its empirically superior BMI alignment (0.7% error vs. 3.1% for Devine female; Peterson et al., 2016). The original Robinson coefficients (48.67/1.65) are used, not the rounded versions (49/1.7).

The sex-differentiated anchor selection is independently supported by Hudson et al.'s (2024) systematic review of 33 papers, which found consistent evidence that females work at greater relative exercise intensity during load carriage at equivalent absolute loads, and identified frontal and horizontal plane biomechanical differences in loaded gait by sex. The known limitations of both formulas — no accounting for body composition, muscle mass, bone density, ethnic variation, or aging — are acknowledged and partially mitigated by the inclusion of BMI-derived anchors.

METHODOLOGY: CONSTRUCTION OF THE FIVE-TIER ARRAY

4.1 Array Architecture

The proposed framework generates five pack weight values for any given individual based on three inputs: height, actual body weight, and biological sex. These five values are derived from three fixed clinical anchors and two variable percentage-of-actual-weight calculations, then sorted from largest to smallest to produce a tiered gradient.

Anchor 1 (NIH Median): 10% of the body weight corresponding to a BMI of 21.7 at the individual's height. Calculation: Weight (lbs) = 21.7 × (Height in meters)² × 2.20462. The BMI value of 21.7 represents the mathematical midpoint of the WHO normal weight classification range (18.5–24.9), calculated as (18.5 + 24.9) ÷ 2 = 21.7. This is derived from the structural midpoint of the clinically defined normal weight range, not from population mean BMI data.

Anchor 2 (IBW): 10% of the sex-specific IBW at the individual's height. Male: Devine (1974); Female: Robinson et al. (1983, original coefficients).

Anchor 3 (NIH Floor): 10% of the body weight corresponding to a BMI of 18.5 at the individual's height, representing the lower boundary of the WHO normal weight classification.

Variable 1 (Upper): 8.3% of the individual's actual body weight. Variable 2 (Lower): 7.7% of the individual's actual body weight.

4.2 Parametric Optimization Process

The 7.7%/8.3% pairing was identified through iterative testing of candidate percentage pairs against the Devine and Robinson scales across the full adult height spectrum (4'6" to 6'6"). Haisman (1988) identified body weight, aerobic fitness, and load magnitude as the primary determinants of load-carrying ability, establishing that performance decrement under load is not uniform across individuals — informing the use of individual body-composition anchors rather than a single threshold.

The optimization criteria required that the selected pair: (a) maintain proper descending sort order across the widest possible range of realistic height-weight combinations; (b) produce meaningful tier separation (minimum ~0.10 lbs between adjacent tiers); (c) fall below the nonlinear force-increase thresholds documented by Birrell et al. (2007), Matur et al. (2025), and Sturdy et al. (2025); and (d) demonstrate consistent internal relationships against both Devine male and Robinson female IBW anchors.

An important methodological clarification: the optimization criteria are mathematically independent of each other. Criterion (a) — sort order integrity — is a mathematical property of the array architecture that depends only on the arithmetic relationships between the five calculated values. Criterion (c) — falling below nonlinear load thresholds — is a biomechanically sourced constraint. These criteria do not circularly depend on each other: a percentage pair could satisfy (a) without satisfying (c), and vice versa. The 7.7%/8.3% pairing satisfies all four criteria simultaneously. This is a parametric optimization finding, not a hypothesis confirmation.

4.3 The Lesser-Of Gating Rule and Factor of Safety Analogy

When the 8.3% actual-weight value crosses above the 10% IBW value in the sorted array, this inversion signals that actual weight has exceeded the load-bearing assumptions embedded in the IBW formula. In such cases, the IBW-derived anchor functions as a protective ceiling.

This lesser-of gating logic is analogous to the Factor of Safety methodology applied in occupational load carriage standards. ISO 11228-1:2021 (Ergonomics — Manual Handling — Part 1: Lifting, Lowering and Carrying) codifies the principle that physical capacity reduces with age and body size, applying conservative safety margins to load limits for occupational populations. The NIOSH Revised Lifting Equation (Waters et al., 1994) applies graduated multipliers for individual and situational variables rather than a single universal limit. This framework adopts the same structural logic.

The critical distinction: unlike engineering applications of Factor of Safety, which apply to known, tested material properties, the thresholds in this framework are derived from clinical estimates. The IBW anchors are theoretical height-referenced skeletal estimates, not measured physiological load limits. The Factor of Safety analogy describes structural logic, not empirical precision.

4.4 Computational Precision Standard

All formula constants are used exactly as published in primary sources without rounding. The kg-to-lb conversion factor (2.20462) is carried to five decimal places. Intermediate calculations are maintained at four decimal places. Final display values are rounded to two decimal places using standard half-up rounding.

RESULTS

5.1 Sample Array Output

To illustrate the framework's output, Table 2 presents the five-tier array for a representative input: Female, 5'2", 130 lbs. Note that for this individual, whose actual weight (130 lbs) is approximately 13.5% above Robinson IBW (114.55 lbs), the array's gating rule does not trigger — the IBW anchor falls in the second tier, and the percentage-of-actual-weight values fall below it. For a more divergent individual —

say, Female, 5'2", 200 lbs — the 8.3% actual-weight value (16.6 lbs) would exceed the 10% Robinson IBW value (11.46 lbs), and the gating rule would activate, capping the recommendation at 11.46 lbs.

Table 2

*Five-Tier Array for Female, 5'2", 130 lbs. *Value calculated using original Robinson coefficients (48.67/1.65); rounded coefficients (49/1.7) produce 11.55 lbs.*

Tier Label	Value (lbs)	Source Calculation	Derivation	% of Actual
Max Cap	13.61	10% NIH Median (BMI 21.7)	Weight at BMI 21.7 × 10%	10.47%
Borderline	11.46*	10% Robinson IBW	48.67 + 1.65×(62−60) × 2.20462 × 10%	8.81%
Optimized	10.79	8.3% of Actual	130 × 0.083	8.30%
Ultralight	10.01	7.7% of Actual	130 × 0.077	7.70%
Expert Ultralight	9.62	10% NIH Floor (BMI 18.5)	Weight at BMI 18.5 × 10%	7.40%

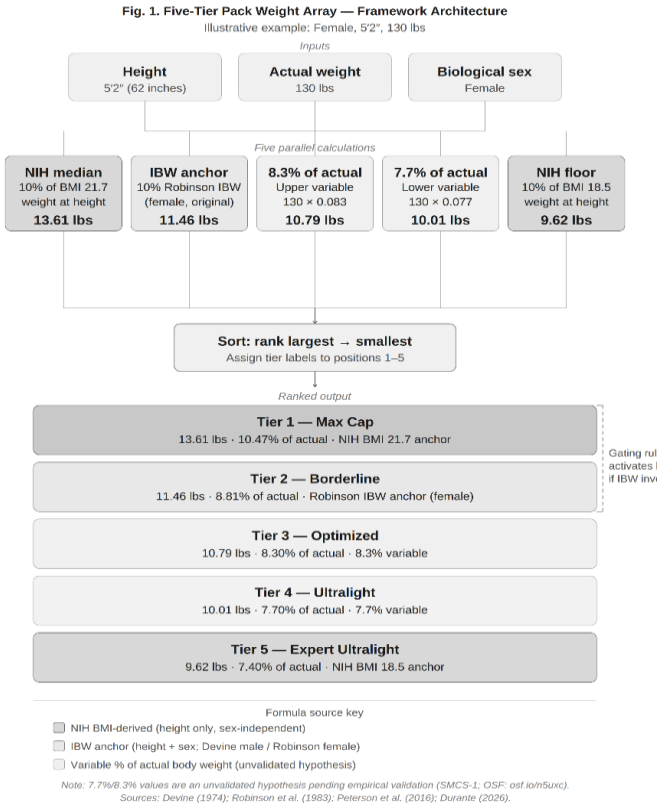
Fig. 1. Five-Tier Pack Weight Array — Framework Architecture
Illustrative example: Female, 5'2", 130 lbs
Inputs
Height
5'2" (62 inches)
Actual weight
130 lbs
Biological sex
Female
Five parallel calculations
NIH median
10% of BMI 21.7 weight at height
13.61 lbs
IBW anchor
10% Robinson IBW (female, original)
11.46 lbs
8.3% of actual
Upper variable
130 × 0.083
10.79 lbs
7.7% of actual
Lower variable
130 × 0.077
10.01 lbs
NIH floor
10% of BMI 18.5 weight at height
9.62 lbs
Sort: rank largest → smallest
Assign tier labels to positions 1–5
Ranked output
Tier 1 — Max Cap
13.61 lbs · 10.47% of actual · NIH BMI 21.7 anchor
Tier 2 — Borderline
11.46 lbs · 8.81% of actual · Robinson IBW anchor (female)
Tier 3 — Optimized
10.79 lbs · 8.30% of actual · 8.3% variable
Tier 4 — Ultralight
10.01 lbs · 7.70% of actual · 7.7% variable
Tier 5 — Expert Ultralight
9.62 lbs · 7.40% of actual · NIH BMI 18.5 anchor
Formula source key
NIH BMI-derived (height only, sex-independent)
IBW anchor (height + sex; Devine male / Robinson female)
Variable % of actual body weight (unvalidated hypothesis)
Note: 7.7%/8.3% values are an unvalidated hypothesis pending empirical validation (SMCS-1; OSF: osf.io/n5uxc).
Sources: Devine (1974); Robinson et al. (1983); Peterson et al. (2016); Durante (2026).

5.2 Coefficient Drift Quantification

Table 3 quantifies divergence between original and rounded Robinson female coefficients across the height spectrum.

Table 3

Robinson Female IBW Divergence: Original vs. Rounded Coefficients. All values in lbs.

Height	Original (48.67/1.65) lbs	Rounded (49/1.7) lbs	Divergence (lbs)
5'0"	107.30	108.03	0.73
5'2"	114.55	115.52	0.97
5'6"	129.27	130.73	1.46
5'10"	143.78	145.73	1.95
6'2"	158.29	160.72	2.43
6'6"	172.76	175.49	2.73

5.3 IBW Formula Alignment with BMI

Comparative alignment analysis, following Peterson et al. (2016), confirms differential accuracy of IBW formulas mapped against BMI-derived weight values across the 95% height range.

Table 4

IBW Formula Alignment with BMI Values, adapted from Peterson et al. (2016). Error = integrated percent error over the 95% height range.

Formula	Sex	Best-Fit BMI	Alignment Error
Peterson (2016)	Both	Any (user-set)	0.5%
Robinson (1983)	Male	22.5	0.4%
Robinson (1983)	Female	21.0	0.7%
Devine (1974)	Male	22.8	2.1%
Devine (1974)	Female	21.3	3.1%
Hamwi (1964)	Male	23.4	3.9%
Hamwi (1964)	Female	21.2	2.6%

5.4 Pre-Emptive Peer Review Challenge Map

Table 5 catalogs the eight strongest anticipated reviewer objections to this paper's premises, their argument type, estimated disposition risk, and the sections in which each is addressed. This table is provided in the spirit of transparent methodological disclosure and to assist readers in evaluating the paper's evidential chain.

Table 5

Anticipated Peer Review Challenges and Pre-Emptive Responses. Disposition risk categories: Outright rejection / Major revision request / Expected and acknowledged.

Challenge	Type	Disposition Risk	Addressed In
10% guideline has empirical support in plantar pressure data	Contradictory evidence	Outright rejection	Section 2.4 (Chicharro-Luna et al., 2026); Section 6.1 discussion of plantar vs. skeletal loading distinction
Recreational load study: 30% BW limit proposed	Contradictory evidence	Major revision request	Section 2.4 and Limitations (Section 7); population context differentiated
IBW not designed for load carriage	Construct validity	Major revision request	Section 3.1 and Section 6.8 (purpose of IBW anchor explicitly stated as skeletal reference, not load limit)
Parametric optimization is circular	Methodological	Major revision request	Section 4.2 (criteria independence clarified); Section 6.9
COI: author sells a calculator based on this framework	Bias	Disclosure required / rejection risk	COI statement; preprint + OSF pre-registration provides transparency shield
Self-optimized pack weight is not a valid proxy for safe load	Epistemological	Major revision request	Phase 2 section (Section 8); Section 6.10
No direct empirical data on pilgrimage trekking populations	External validity	Expected — acknowledged	Limitations (Section 7); Phase 2 section establishes remediation path
Single-author non-institutional research	Credibility	Editor screening risk	ORCID, OSF pre-registration, AI disclosure, transparent methodology

DISCUSSION

6.1 The Fundamental Problem with Percentage-of-Actual-Weight Guidelines

The central argument of this paper is specific: when actual body weight substantially exceeds ideal body weight, a percentage-of-actual-weight guideline produces a recommendation calibrated to mass the skeleton did not evolve to support. This argument applies to a defined population subset — overweight individuals — and does not claim that the 10% guideline is universally wrong.

Consider two individuals of identical height (5'10" male): one weighing 170 lbs (BMI 24.4, normal weight) and one weighing 250 lbs (BMI 35.9, Class II obesity). A 10% guideline prescribes 17 lbs and 25 lbs respectively. Yet both share approximately the same skeletal frame. The additional 80 lbs in the second individual is predominantly adipose tissue, which contributes to ground reaction forces but does not increase the structural capacity of the load-bearing skeleton. The five-tier array addresses this by incorporating height-based anchors that are independent of actual weight, and its gating rule activates to cap the recommendation for the heavier individual at the IBW-derived ceiling.

6.2 The Non-Linear Scaling Problem and Sex-Differentiated Response

Birrell et al. (2007) demonstrated alterations in ground reaction forces with increasing backpack load, establishing non-linear biomechanical cost scaling. Matur et al. (2025) found that at 12% body weight, backpack carriage reduced erector spinae and multifidus activation while restricting spinal range of motion.

Sturdy et al. (2025) demonstrated that walking slope and backpack load interact to increase peak and impulsive lumbar joint contact forces. Hudson et al.'s (2024) systematic review of 33 studies found that females work at greater relative exercise intensity under equivalent absolute loads, establishing sex as a meaningful variable in load-carriage framework design. Simpson, Munro & Steele (2011) found that 20% BW loads induced significant postural changes and perceived exertion increases in female recreational hikers over 8 km, with 30% BW representing the upper functional limit.

The framework's 7.7%–8.3% range falls well below the 20%–30% BW thresholds identified in recreational female studies, and below the 12% threshold at which Matur et al. (2025) observed adverse EMG changes. This consistency across multiple studies does not validate the specific percentage pair — that remains the purpose of Phase 2 — but it confirms that the framework's output is directionally consistent with the independent recreational literature.

6.3 Implications of the Kang et al. (2019) Pediatric Findings

Kang et al.'s (2019) comparative study of seven IBW calculation methods in 1,442 pediatric patients found that the Devine method produced the largest mean difference from the McLaren reference method in older children (mean difference 6.04 kg, $p < 0.001$). This supports the present paper's decision to use Robinson's more empirically grounded formula for the female IBW anchor, and independently confirms that Devine's formula produces clinically significant divergence from reference values at height extremes.

6.4 Age-Related Gait Considerations in the Target Population

Liang (2024) demonstrated that age affects the dynamic interaction between kinematics and gait stability, with older adults showing significantly different center-of-mass and base-of-support relationships during walking. Siragy et al. (2024) documented age-related differences in mediolateral margin of stability. These findings underscore that load-carriage thresholds established in young military populations cannot be extrapolated without adjustment to the 46–65 cohort that constitutes 41.3% of Camino pilgrims. The five-tier array does not yet incorporate an explicit age correction — that is one of the variables the Phase 2 study is designed to investigate through age-stratified subgroup analysis.

6.5 The Peterson Universal Equation as Validation Framework

Peterson et al.'s (2016) universal equation — Wt (lb) = 5 × BMI + (BMI ÷ 5) × (Ht − 60 in) — provides an independent verification path for the BMI 18.5 and BMI 21.7 anchor calculations that does not depend on the IBW formulas themselves. Future iterations of the framework may incorporate this equation directly to replace the IBW anchor with a BMI-aligned alternative, addressing Shah et al.'s (2006) recommendation to abandon linear IBW formulas.

6.6 Field Evidence from Backpack Hiking Research

Stoltzfus et al. (2022) conducted a prospective cohort study of 1,206 hikers at Philmont Scout Ranch and found that obesity and prior injury history were associated with musculoskeletal injury risk during 12-day backpacking treks. The finding that counseling of obese individuals regarding pack weight management may mitigate injury occurrence is directly consistent with the body-composition-adjusted approach proposed here. Stoltzfus et al. (2022) represents the most relevant prospective field data currently available for recreational backpack hiking, and the planned Phase 2 survey is designed to extend this evidence base to the adult pilgrimage population.

6.7 The Inference Gap: Military Evidence at Light Recreational Loads

A reviewer may reasonably ask how evidence from military populations carrying 8–35 kg loads informs a recreational framework proposing 7–11 lb pack weights. The relationship is directional rather than scalar. The military literature establishes the direction and nature of biomechanical effects — nonlinear force increases, sex-differential responses, the interaction of slope and load at the lumbar spine — without providing specific recreational thresholds. The 7.7%/8.3% hypothesis values are derived from the IBW and BMI reference framework, not extracted from military load data. The military literature is cited to establish principles that motivate body-composition adjustment; the specific values are parametric optimization outputs against clinical anchors.

6.8 Why IBW Formulas Constitute a Valid Skeletal Reference — Anticipated Challenge and Response

The strongest methodological objection to this paper is likely to be: IBW formulas were developed for pharmacokinetic drug dosing, not for estimating skeletal load-bearing capacity. Their use in this context is a category error. This objection deserves direct engagement.

The paper does not claim that IBW equals physiologically measured skeletal load capacity. It claims that IBW — being a formula that outputs body weight as a function of height alone, independent of adipose tissue mass — is a better proxy for skeletal frame size than actual body weight in individuals with elevated BMI. This is a weaker and more defensible claim. The logic is analogous to how IBW is used in ARDSNet ventilator tidal volume calculations: the formula is used not because it was designed to measure lung capacity, but because height-based IBW provides a better predictor of lung size than actual body weight in overweight patients. The same structural logic applies here.

Reviewers may further argue that even if IBW is a better proxy for skeletal frame than actual weight, there is no published research establishing a quantitative relationship between IBW and load-carriage safety thresholds. This is correct, and the paper acknowledges it. The IBW anchors in the five-tier array are theoretical estimates that establish reference points, not empirically validated load limits. The framework is proposed as a hypothesis — that IBW-anchored recommendations will better correspond to the pack weights that experienced trekkers converge on in the field — and Phase 2 is designed to test that hypothesis.

6.9 The Optimization Circularity Challenge — Anticipated and Addressed

A second anticipated methodological objection: the parametric optimization process is circular. The 7.7%/8.3% pair was selected, in part, because it falls within the 'biomechanically plausible range' — but that range was itself informed by the same military literature the paper uses as evidence. The selection criteria and the evidentiary basis are therefore not independent.

This objection is partially correct and deserves honest acknowledgment. Criterion (c) in Section 4.2 — falling below nonlinear force-increase thresholds — does use military load-carriage literature to constrain the optimization space. However, three things limit the circularity risk. First, the military literature constrains the upper bound of the optimization space (ruling out values above known biomechanical disruption thresholds) but does not determine the specific selected values — many pairs satisfy criterion (c). Second, the primary optimization criteria — sort order integrity (a) and tier separation (b) — are purely mathematical properties of the array architecture, entirely independent of the biomechanical literature. Third, and most importantly, the paper explicitly frames 7.7%/8.3% as a testable prediction, not a finding. Whether these specific values correspond to real-world trekker self-optimization behavior is an empirical question that Phase 2 will answer. If Phase 2 data cluster at 9% or 6%, the hypothesis is refuted. The circularity concern would only be fatal if the paper claimed confirmation; it claims only that the values are defensible candidates for empirical testing.

6.10 The Epistemological Challenge: Self-Optimization as a Validity Criterion

A third substantive challenge: why should 'self-optimized pack weight' — what experienced trekkers voluntarily carry after shedding unnecessary items — be treated as a valid proxy for physiologically safe load? People also self-optimize their diet toward foods that taste good rather than foods that are nutritionally optimal. Self-selection behavior does not validate a biomechanical threshold.

This is the most philosophically sophisticated objection and it is partially correct. Self-optimized pack weight is not a direct measure of safe load. It is a behavioral proxy for the intersection of perceived exertion tolerance, injury risk experience, and essential gear requirements across multiple days of walking. The argument is not that whatever trekkers choose is safe; it is that experienced trekkers' convergent behavior over hundreds of kilometers, after experiencing the biomechanical consequences of their initial load, represents ecologically valid information about the load range at which the human body can sustain multi-day walking without functional impairment. This is a weaker epistemological claim than 'self-optimization equals safety,' and the paper acknowledges it explicitly.

The Phase 2 hypothesis is therefore stated carefully: that the median self-optimized ratio will fall within 7.7–8.3%. This is a prediction about behavior, not a claim about safety limits. Confirming the behavioral prediction would constitute evidence consistent with the framework — not proof of its validity. The causal chain from self-optimization to physiological safety requires additional empirical steps that Phase 2 does not and cannot provide on its own.

LIMITATIONS

This study has eight acknowledged limitations.

First, this paper is a literature synthesis and mathematical modeling exercise, not an empirical study. The 7.7%/8.3% pairing has not been validated against field data from actual trekkers.

Second, the foundational load-carriage studies were conducted primarily on young military-age male subjects. Extrapolation to middle-aged and older recreational trekkers introduces population-validity uncertainty that cannot be quantified without age-stratified, civilian-population load-carriage research.

Third, the IBW formulas used as anchor calculations were derived from predominantly white, middle-class American and European populations from the 1960s–1980s. Their applicability across ethnic groups, body types, and contemporary population distributions is limited (Shah et al., 2006; Peterson et al., 2016).

Fourth, the framework does not account for terrain type, elevation profile, ambient temperature, pack design and fit characteristics, or individual fitness level. The interaction of slope and load documented by Sturdy et al. (2025) is particularly relevant for routes with significant elevation change.

Fifth, IBW formulas address skeletal frame size as a proxy but do not directly measure load-bearing capacity. The IBW-to-load-capacity inference step is theoretical and unsupported by direct empirical measurement in load-carriage research. This is the framework's most significant structural limitation.

Sixth, the paper proposes that self-optimized pack weight is a meaningful behavioral proxy, but as discussed in Section 6.10, self-optimization behavior is not a validated safety measure. The Phase 2 study will test the behavioral prediction but cannot substitute for biomechanical load capacity research.

Seventh, sample sizes in some cited studies are small (Shymon et al., 2014, N=6; Liang, 2024, N=30; Simpson et al., 2011, N=15), limiting the precision of threshold estimates derived from those studies.

Eighth, the sex-differentiated IBW anchor selection addresses biological sex as a binary variable and does not account for gender identity, hormonal status, or body composition variation within sex categories. Future refinements should incorporate more nuanced body composition metrics.

PHASE 2: PACK WEIGHT ADJUSTMENT PATTERNS IN RECREATIONAL TREKKERS ON THE CAMINO DE SANTIAGO: A CROSS-SECTIONAL OBSERVATIONAL SURVEY PROTOCOL — THE SILVER MAJORITY CAMINO STUDY (SMCS-1)

The theoretical framework presented in this paper generates a testable prediction: when recreational trekkers self-optimize their pack weight through trial and field experience on the Camino de Santiago, the resulting final pack weights will cluster near 7.7–8.3% of actual body weight for the median participant. This prediction follows from the framework's composition-adjusted logic: if IBW-anchored recommendations better approximate the load range consistent with multi-day walking than actual-weight percentages, then field convergence should occur below 10% of actual weight and above a minimal functional threshold.

A pre-registered prospective survey protocol has been developed to test this prediction. The study design, analysis plan, and primary hypothesis have been registered with the Open Science Framework at osf.io/z46vs prior to data collection, establishing the analytical framework on public record. Pre-registration is a methodological requirement for any empirical research that follows from this theoretical paper, and its completion prior to Phase 2 data collection is non-negotiable.

The planned survey will collect: demographic data (age, biological sex, height, actual body weight); initial pack weight at departure by digital luggage scale; items removed or shipped during route; and final self-optimized pack weight at the point the participant reports the pack felt right for sustained daily walking. The primary analysis will compute the ratio of final self-optimized pack weight to actual body weight and examine the distribution against the 7.7–8.3% hypothesis range.

Target enrollment: 2,500 completed responses. Sample size was determined using a precision-of-estimation approach: at N=2,500, assuming a conservative standard deviation of 0.025 for the pack weight ratio (estimated from Stoltzfus et al., 2022), the 95% confidence interval half-width on the median ratio is approximately ±0.002, sufficient to determine whether the observed median falls within, above, or below the hypothesized 7.7–8.3% range. This study was determined to qualify for exemption from IRB review under 45 CFR 46.104(d)(2) prior to data collection. A formal exemption analysis memorandum was completed by the principal investigator on June 16, 2026, in accordance with OHRP guidance for unfunded independent research. This determination is documented in Project 21F LLC / ETSPR IRB Self-Determination Memorandum SMCS1-v1.4. Survey response data will be stored on a secured private server with restricted access, encrypted at rest and in transit, in compliance with applicable data protection

standards. De-identified participant data will be deposited in a publicly accessible repository (Zenodo) upon study completion, in accordance with FAIR data principles.

This paper explicitly acknowledges that even a Phase 2 finding confirming the 7.7–8.3% behavioral prediction would not, by itself, establish that these values represent physiologically safe load thresholds. Confirmation would constitute evidence consistent with the body-composition-adjusted framework, warranting further investigation including objective biomechanical measurement, injury rate comparison across pack weight tiers, and prospective longitudinal study design. The research program that begins with this theoretical paper and Phase 2 behavioral survey is a foundation, not a conclusion.

CONCLUSION

The 10% pack weight guideline, as currently circulated in the recreational trekking community, is the product of a multi-decade Truncation Error in which qualified military research findings were progressively simplified, decontextualized, and applied to a population for which they were never intended. Recent empirical evidence — including a plantar pressure study specifically in long-distance hikers (Chicharro-Luna et al., 2026) — provides partial support for the 10% threshold as a plantar loading boundary, while leaving the body-composition-adjusted skeletal load capacity question unresolved.

This paper proposes that the question of optimal pack weight in overweight recreational trekkers cannot be answered with a single number referenced to actual weight. A five-tier array incorporating clinical IBW and BMI anchors alongside actual-weight percentages provides a graduated set of recommendations that adapts to body composition. The key insight is not the specific values of 7.7% and 8.3%, which await

empirical validation, but the structural observation that percentage-of-actual-weight guidelines systematically fail when actual weight exceeds ideal weight — and this failure is diagnostically visible when a framework includes both types of reference points.

This paper has documented its own strongest vulnerabilities: the absence of direct empirical evidence linking IBW to load-bearing capacity; the epistemological limitations of self-optimization as a safety proxy; the partial counter-evidence from the recreational hiking literature; and the theoretical rather than validated nature of the proposed framework. These are not weaknesses that can be resolved within a literature synthesis paper. They are the specification for the empirical work that must follow.

The pre-registered Phase 2 study will either confirm, refine, or refute the behavioral prediction. Either outcome advances the field.

CONFLICT OF INTEREST STATEMENT

The author is the founder of Project 21F LLC and the European Trekking Standard & Protocol Registry (ETSPR), which operates etspr.org (institutional research domain) and stellarumpath.com (commercial entity in the Camino de Santiago planning market). The mathematical framework described in this paper is implemented in a publicly available calculator application developed by the author's organization. This constitutes a direct financial conflict of interest: commercial products derived from this framework may benefit if the framework gains scientific credibility. No external funding was received for this research. This conflict is disclosed fully and has been present in every version of this paper. The author's position is that transparency about the conflict, combined with pre-registration of the validation study and open publication of all source data and computational methods, provides the appropriate mitigation. Readers and reviewers are invited to weigh the evidence accordingly.

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TRANSLATION VERSIONS — STATUS

This section records all 21 non-English translations published as independent Zenodo records, each with its own reserved DOI, linked to the canonical English record via the Related Identifiers field. Full translation registry: https://doi.org/10.5281/zenodo.20509304

Language	Zenodo DOI	Status	Priority
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German (DE)	10.5281/zenodo.20496676	PENDING REVIEW	2
Italian (IT)	10.5281/zenodo.20496694	PENDING REVIEW	3
Portuguese/BR (PT)	10.5281/zenodo.20496706	PENDING REVIEW	4
Korean (KO)	10.5281/zenodo.20496714	PENDING REVIEW	5
French (FR)	10.5281/zenodo.20496718	PENDING REVIEW	6
Japanese (JA)	10.5281/zenodo.20496732	PENDING REVIEW	7
Mandarin Chinese (ZH)	10.5281/zenodo.20508637	PENDING REVIEW	8
Hindi (HI)	10.5281/zenodo.20508688	PENDING REVIEW	9
Dutch (NL)	10.5281/zenodo.20508704	PENDING REVIEW	10
Swedish (SV)	10.5281/zenodo.20508736	PENDING REVIEW	11
Polish (PL)	10.5281/zenodo.20508765	PENDING REVIEW	12
Arabic (AR)	10.5281/zenodo.20508787	PENDING REVIEW	13
Russian (RU)	10.5281/zenodo.20508813	PENDING REVIEW	14
Norwegian (NO)	10.5281/zenodo.20508929	PENDING REVIEW	15
Turkish (TR)	10.5281/zenodo.20508946	PENDING REVIEW	16
Czech (CS)	10.5281/zenodo.20508966	PENDING REVIEW	17
Indonesian/Malay (ID)	10.5281/zenodo.20508984	PENDING REVIEW	18
Thai (TH)	10.5281/zenodo.20509000	PENDING REVIEW	19
Hungarian (HU)	10.5281/zenodo.20509005	PENDING REVIEW	20
Romanian (RO)	10.5281/zenodo.20509021	PENDING REVIEW	21